PB87-146171

Evaluation of Benthic Macroinvertebrate Biomass Methodology. Part 2 Field Assessment and Data Evaluation

(U.S.) Environmental Protection Agency
Washington, DC

1985

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-146171

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/J-85/459	2.
3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE: An Evaluation of Benthic Macroinvertebrate Biomass Methodology: Part 2. Field Assessment and Data Evaluation (Journal Version)	5. REPORT DATE: 1985
	6. PERFORMING ORGANIZATION CODE: EPA/600/16
7. AUTHOR(S): Mason, William J.; Lewis, Philip A.; and Weber, Cornelius I.	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Environmental Protection Agency, Office of Research and Development (RD-682), 401 M Street, S.W., Washington, D.C. 20460	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: U.S. Environmental Protection Agency, Office of Research and Development (RD-682), 401 M Street, S.W., Washington, D.C. 20460	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE: EPA/600/16

15. SUPPLEMENTARY NOTES

Environ. Monitoring & Assess., 5:399-422, May 1985

16. ABSTRACT

This study shows that biological assessments of water quality status using biomass estimates of wet, dry, and ash-free dry weights and counts of individual organisms from a small, headwater stream in southwestern Ohio provide essentially similar results concerning the impact of a sewage treatment plant discharge. Of the indices of biotic status for the stream employed for data evaluation; Diversity Index (D), Community Diversity Index ($\bar{d}$), Trophic Condition Index (TCI), and Empirical Biotic Index (EBI), the latter two provided evaluations most consistent with benchmark water chemistry and physics information concerning the trophic status of the stream. In addition, the percent composition of macroinvertebrate taxa by pollutional category; 'clean water', 'facultative', and 'pollution tolerant', as ascribed using TCI and EBI ranges for individual taxa collected in combination of Ekman grab, rock-filled basket sampler and drift net samples, proves adequate for interpretation of biotic status.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Biomass	Index		
Benthic	Trophic		
Macroinvertebrate	Pollution		
Assessments	Sampling		
Data	Analytical Methods		

18. DISTRIBUTION STATEMENT: RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)*: UNCLASSIFIED	21. NO. OF PAGES: 26
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

EPA/600/J-85/459
JOURNAL ARTICLE

AN EVALUATION OF BENTHIC MACROINVERTEBRATE BIOMASS METHODOLOGY

Part 2. Field Assessment and Data Evaluation

WILLIAM T. MASON, Jr.*, PHILIP A. LEWIS**,
and CORNELIUS I. WEBER**

(Received 21 June, 1984)

Abstract. This study shows that biological assessments of water quality status using biomass estimates of wet, dry, and ash-free dry weights and counts of individual organisms from a small, headwater stream in southwestern Ohio provide essentially similar results concerning the impact of a sewage treatment plant discharge. Of the indices of biotic status for the stream segment employed for data evaluation; Diversity Index (D), Community Diversity Index ($\bar{d}$), Trophic Condition Index (TCI), and Empirical Biotic Index (EBI), the latter two provided evaluations most consistent with benchmark water chemistry and physics information concerning the trophic status of the stream. In addition, the percent composition of macroinvertebrate taxa by pollutional category; 'clean water', 'facultative', and 'pollution tolerant', as ascribed using TCI and EBI ranges for individual taxa collected in combination of Ekman grab, rock-filled basket sampler and drift net samples, proves adequate for interpretation of biotic status.

1. Introduction

In recent years, the need for rapid assessment procedures for evaluation of point and nonpoint source pollution impacts on aquatic life has escalated in response to national laws, such as the Clean Water Act (PL 95–217), and state legislation dealing with environmental quality. These laws, and supporting regulations, require several analyses, including aquatic life, to determine the water quality status as related to legally supported state water quality standards. Currently, the states and EPA Regional Offices review the status of waters based on instream ambient water conditions for priority waters. A 'use attainability analysis', involving evaluation of the physical, chemical and biological quality of waters and economic factors, is conducted if a preliminary analysis of historical monitoring data indicates that ambient stream conditions do not, or are not, expected to meet designated state water quality standards, even after implementation of best available technology controls for point source discharges. The labor and funds available to conduct use attainment assessments are limited, which in turn, place high value on assessment methods that are cost effective and provide meaningful results for water use decisionmaking.

Currently, there are hundreds of 'standard methods' for use in measuring impacts of pollution discharges to biological communities. Most of these methods employ counts of individuals and diversity (kinds) of organisms present in the community. The

* Aquatic Ecologist, Office of Environmental Processes and Effects Research, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC. 20460. Currently, Division of Biological Services, U.S. Fish and Wildlife Service, Washington, DC. 20240.
** Aquatic Biologist, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, and Chief, Biological Methods Branch, respectively.

Environmental Monitoring and Assessment 5 (1985) 399–422. 0049–6979/85.15.
1985 *by D. Reidel Publishing Company.*

'reference station' approach is used where aquatic life communities in affected areas are compared to life in unaffected areas. Generally, high counts and low diversity are characteristic of environments stressed by heavy loads of organic wastes, while both low counts and diversity are found in habitats affected by toxic and acidic pollutants. Clean water areas have moderate to high counts of macroinvertebrates with relatively even distribution of the individuals among the kinds that are present.

We hypothesized that estimates of macroinvertebrate biomass could potentially provide assessments of biological quality more efficiently than conventional tedious, labor intensive counts of individual organisms. Secondly, we hypothesized that biomass, or weight of tissue, that is supported by the watershed could be more intrinsic to characterizations of pollution-caused changes in community structure than individual counts. To test these hypotheses, we selected a small stream in Southwestern Ohio receiving a sewage treatment plant (STP) discharge. Standard collection gear (APHA, 1981) was employed for collection of stream macroinvertebrates, and data were evaluated using counts of individuals and several popular biotic indices of water quality status.

The analytical phase of this study (Mason *et al.*, 1983) contains information on the study area and quality assurance aspects of laboratory derived biomass estimates, such as effects of drying and ashing times on weights of tissue. This paper presents data synthesis and interpretation from Part 1. 'Laboratory Analytical Methods' to test our hypotheses.

2. Study Area-Water Physics and Chemistry

2.1. General conditions

The study area is a five mile (8.1 km) reach of the East Fork, Little Miami River (Figure 1), a small headwater stream, located about 30 miles (48.3 km) east of Cincinnati, Ohio in a rural setting. The predominant geologic type is glacial till and land use is agricultural. The stream segment received a single point source discharge from the Williamsburg, Ohio activated sludge STP. During summer the discharge from the STP outfall was 9.5 l sec^{-1} (2.5 gal sec^{-1}). However, as the discharge was intermittent and the pipe covered by flashy flow conditions, actual instream concentrations of the discharge could not be determined.

During normal summer flow the stream was 20–50 yards (18.3–45.7 m) wide and one (0.3 m) to three feet (1.0 m) deep. However, after heavy rains the stream would become swollen, carry large silt loads, and attain depths of six feet (1.8 m) or more in a few hours. This flashy flow (Figure 2) was evident in measurements for the year 1971 taken by U.S. Geological Survey at Station 1. The stream bottom type consisted of limestone bedrock overlain with sand, silt, gravel and rubble. The habitat alternated between riffle and pool, and the banks were heavily wooded with an estimated 50–75% closure at Station 1, 2E and 2W. Stations 3 and 4 (east bank) were bordered by a high wooded bluff.

The specific conductance, alkalinity, carbonate hardness, total phosphorus, ortho-

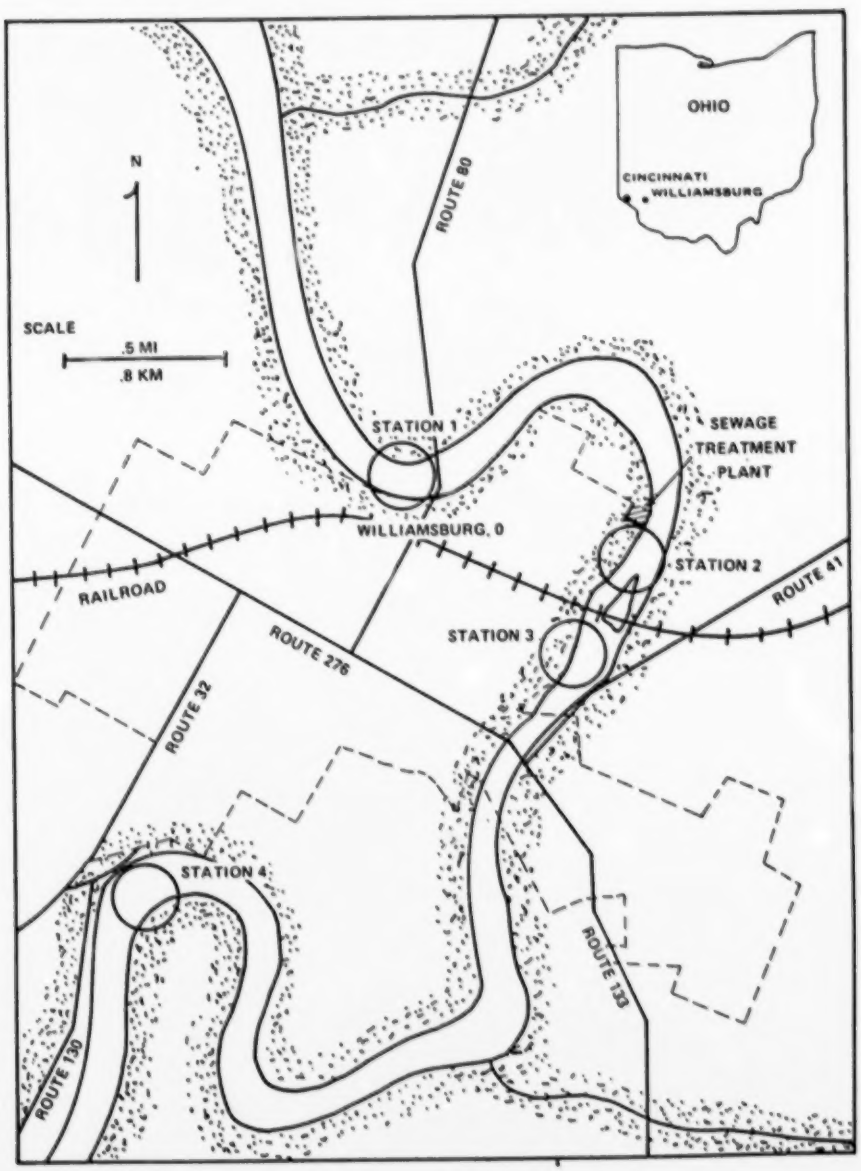

Fig. 1. East Fork, Little Miami River, Williamsburg, Ohio.

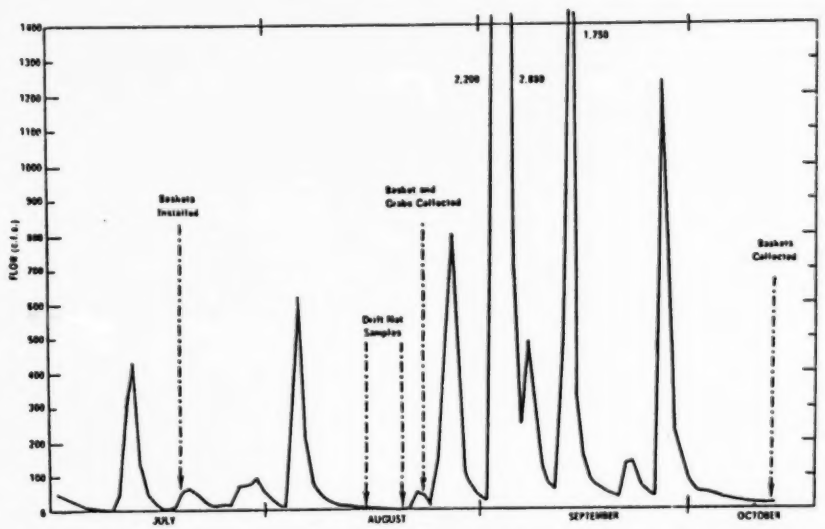

Fig. 2. Daily flow measurements at station 1 East Fork, Little Miami River, Williamsburg, Ohio during 1971 and sampling periods for macroinvertebrate collections.

phosphate and Kjeldahl nitrogen concentrations were generally higher at Station 2W than at the other stations for July and August 1971, indicating eutrophy during the sampling period. Dissolved oxygen, pH and water temperature were relatively uniform throughout the summer. STP effluent discharge samples collected during August 1971 ranged from 4.5 to 50 mg l^{-1} total organic carbon (TOC) concentrations. Water transparencies for all stations in August were less than 100 JTU.

2.2. Station descriptions

Stations 1 (Figure 1) was located below a riffle, approximately 1/4 mile (0.4 km) downstream from a five foot (1.5 m) low dam that aerates the water and was 1/2 mile (0.8 km) upstream from the Williamsburg STP. Water chemistry data for this station indicate well oxygenated, clean water conditions. The pH varied little during the summer with recorded values near neutral or slightly basic. Specific conductance, hardness, and alkalinity (Figure 3) and total (TP) and dissolved phosphorus (TDP) levels (Figure 4) are typical of streams in the region draining rural areas.

Station 2 (Figure 1) was located at the foot of a riffle, about 20 yards (18.3) below the STP outfall. At Station 2, the stream was divided by a small island, which shielded about 60% of the total stream volume from the STP outfall. Thus, benthic sampling was conducted at two sites designated Station 2W (affected by the STP discharge) and 2E (protected from the STP discharge by the island). At Station 2W the bottom was covered with a layer of flocculent organic matter six inches (15.2 cm) deep near the bank. At Station 2W, the mean specific conductance was higher by 100 mmhos and chlorides

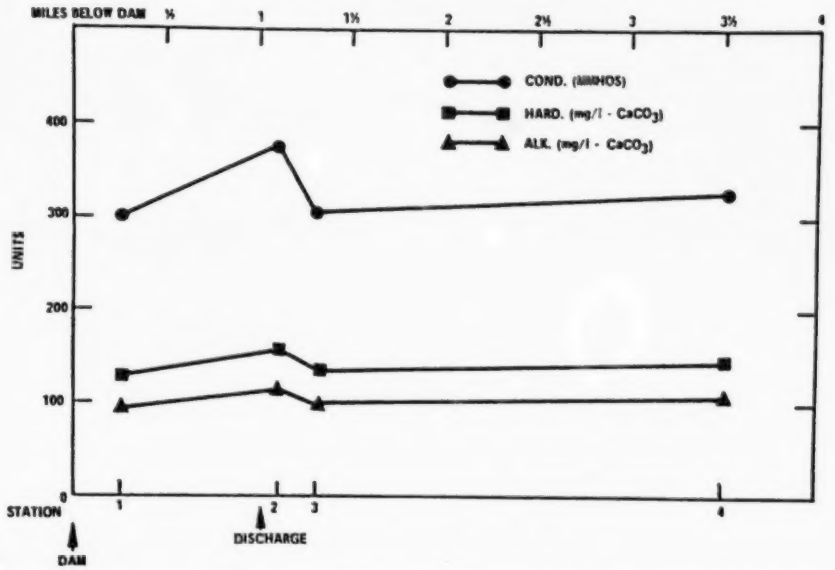

Fig. 3. Mean conductivity, hardness and alkalinity for the study area (weekly samples: July 13–September 27, 1971).

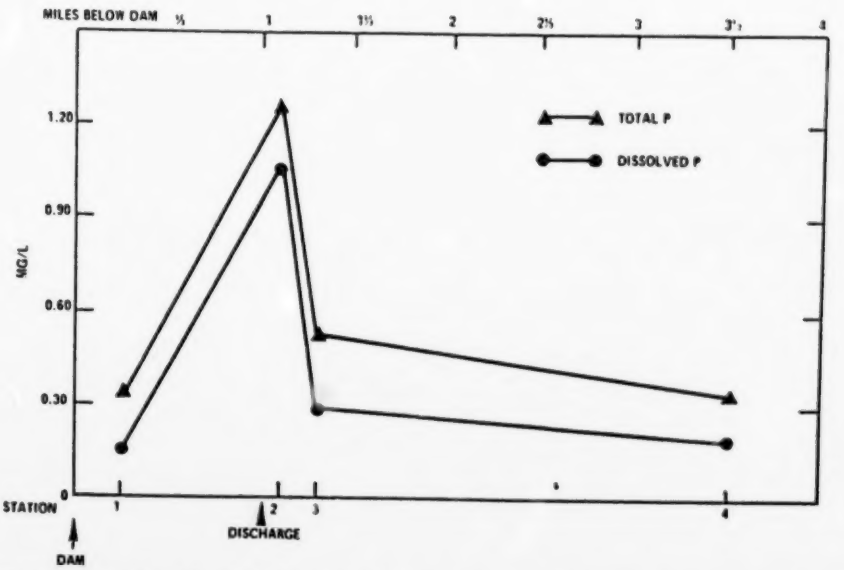

Fig. 4. Mean total and dissolved phosphorus for the study area (weekly samples: July 13–September 27, 1971).

were noticeably higher than at the other stations. During the summer, the mean TP values at Station 2W were about five times the values at Stations 1 and 4, and are considered 'eutrophic', i.e., TP > 0.6 mg l^{-1}. Stations 1, 3 and 4 are in the 'mestrophic' range, i.e., TP between 0.2–0.6 mg l^{-1}.

Station 3 (Figure 1) was located in a riffle area at a railroad bridge approximately $\frac{1}{3}$ mile (0.5 km) downstream from the STP outfall. The river is broad and divided into a series of small rivulets during flooding. Samples were collected about 10 yards (9.1 m) from the left bank, main channel.

Station 4 was located approximately $3\frac{1}{4}$ mile (5.23 km) downstream from the STP, and was approximately 50 yards (45.7 km) downstream from a riffle. The chemical and physical parameters indicated generally improved water quality conditions compared with Stations 1, 2, and 3.

2.3. Station pollutional rank

On the basis of the physical and chemical measurements, the rank of water quality by station from the most to least degraded is; Station 2W, 3, 2E, 1 and 4. Differences in water chemistry for those parameters measured at the latter three stations are slight. These known environmental conditions serve as benchmarks for evaluation of macroinvertebrate data collected in the study.

3. Methodology

3.1. Biological analysis

On August 23, six replicate, 91.4 cm Ekman grab (Figure 5) samples were collected from silt-bottom pools (Mason *et al.*, 1983). The uniformity of bottom substrate materials and depth (riffle habitat) made transect sampling for bottom grabs unnecessary. Figure 2, in addition to daily flow measurements, contains sample collection dates.

Because the limestone bedrock could not be sampled easily by Ekman grab, rock-filled basket samplers (Figure 5) were also employed to collect macroinvertebrates. The 'artificial substrate' baskets were fastened on threaded steel rods imbedded in 40 × 25 × 8 cm concrete slabs. Trial performance tests revealed that during flashy flow periods the slabs had a tendency to 'kite' downstream and to topple. Later, we learned that the best way to anchor artificial substrates in small headwater streams was to drive steel rods into cracks in the bedrock and secure the samplers to the rods with cable clamps. Two replicate basket samplers were exposed at mid-water depth, 30 cm below the surface of the water (total depth 60–80 cm at low flow) at each station from July 19 to August 23, and from August 23 to October 12.

Drift net sampling, conducted the week of August 15–19, consisted of single samples collected at each station during the sample period of one day with rectangular nets (net opening of 15 × 30 cm; 0.40 mm mesh netting). The net was positioned with the opening facing upstream and held 15 cm below the water's surface on steel rods. Drift net data are expressed in numbers of individuals or biomass m^{-3} of water passing through the

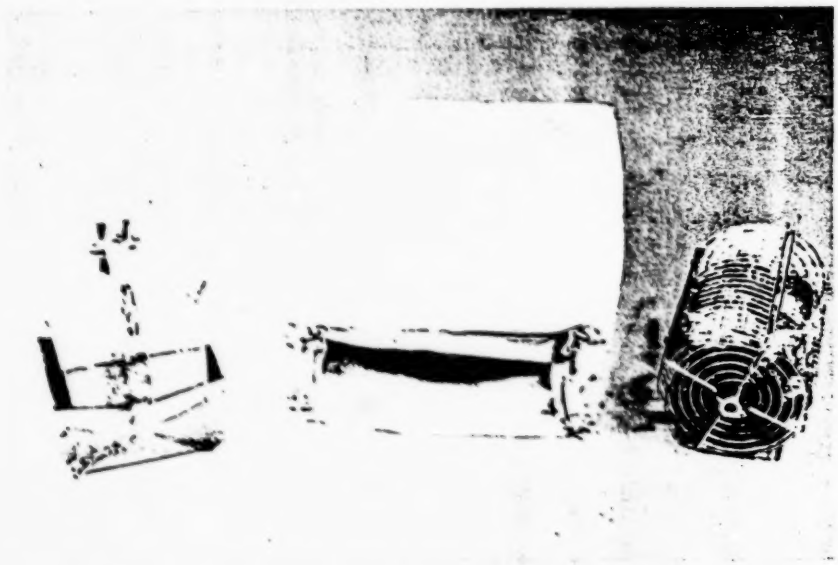

Fig. 5. Sampling gear used for biomass study: (left to right) Ekman grab, drift net, rock-filled basket sampler (simulated substrate).

nets (Lehmkuhl and Anderson 1972). The formula for calculating the number of individuals m^{-3} of water flowing through drift nets (X) is a/bcd, where: a = number of organisms in the sample; b = interval of sampling time in minutes; c = current velocity in m min^{-1}; and d = area of the net opening.

3.2. Data evaluation

Macroinvertebrate data were analyzed for abundance of organisms at various taxonomic levels – Order, Family, Genus, Tribe, and Species – depending on the level of identification possible with existing taxonomic keys. Where possible, species determinations were checked with reference museum specimens and keys. Although the levels of taxonomic definition varied, each level adopted for the various taxa was consistent throughout the study.

Biological indices (Table I) of environmental quality were employed for data evaluation including; Diversity Index (D) and Community Diversity Index ($\bar{d}$) as presented by Wilhm (1970), Trophic Condition Index (TCI) of Brinkhurst *et al.* (1968), and Empirical Biotic Index (EBI) of Chutter (1972). The EBI was modified slightly from a range of 0–10 for species pollutional rank to 0–11. This range provided an equal split of four subunits for each of three major ranks. The reader should be aware that TCI was originally used to measure the trophic status of the Great Lakes influenced by the subtle effects of eutrophication, whereas, the EBI index was designed to demonstrate the impact of point source organic and inorganic waste discharges.

Reproduced from best available copy.

TABLE I

Biological indices

Index	Formula	Where	Pollutional classification
Trophic Condition Index (TCI)	$\frac{\Sigma N_1 + 2\Sigma N_2}{\Sigma N_2}$	N_0 = # intolerant organisms N_1 = # facultative organisms N_2 = # tolerant organisms	0 = Maximum oligotrophy 2.00 = Maximum eutrophy
Empirical Biotic Index (EBI)	$\frac{\Sigma(a \cdot b)}{N}$	a = # in ith species b = quality value (0-10) of ith species	0-2 = clean H_2O 2-4 = slightly polluted H_2O 4-7 = enriched H_2O 7-10 = polluted H_2O
Community Diversity Index ($\bar{d}$)	$\sum_{i=1}^{S} (ni/N \cdot \log_2 ni/N)$	ni = # individuals in the ith species N = total # individuals/sample	1.00 = polluted H_2O 3.00 = clean H_2O
Diversity index (D)	$\frac{S-1}{\log N}$	S = total species N = total # individuals	

The 'tolerance rank' of each taxon required to calculate TCI and EBI is presented in Table II. Species tolerance 'ranks' to pollutional stress were assigned prior to data analysis and based on the authors' experiences with numerous monitoring assessments in the Ohio River Basin Region. Those taxa whose environmental requirements were poorly known were placed in the mid-range of values (0–11). Broad family and generic groupings were treated similarly. As more information on the 'tolerance' of organisms becomes available, biological indices, like the ones proposed by Chutter and Brinkhurst *et al.* (1968), will become more demonstrative.

4. Results and Discussion

The total taxa for Ekman grab, basket sampler and drift net collections for the East Fork, Little Miami River during 1971 are shown in Figure 6. The number of taxa in grab samples was less at Station 2W than the other Stations and contained only chironomid larvae and worms. The Station 2W basket sampler for six weeks ending August 23 had the greatest number of taxa. Basket collections October 12 contained a greater diversity than the August collections and less diversity occurred at Stations 2W and 3 compared to Stations 1 and 4. The drift net collections during the week of August 15 showed little difference in total diversity from Station 1 to Station 3 (Figure 6). The short distance

TABLE II

Macroinvertebrate taxa from the East Fork, Little Miami River, Williamsburg, OH and pollutional categories

TAXA	Trophic Condition Index / Empirical Biotic Index	CATEGORIES N_0 0	1	2	3	N_1 4	5	6	7	N_2 8	9	10	11
Diptera-Chironomidae													
Pentaneurini													
Ablabesmyia mallochi										•			
A. rhamphe								•					
A. aequifasciata							•						
A. aspera				•									
Pentaneura sp.			•										
Guttipelopia sp.							•						
Larsia sp.				•									
Conchapelopia sp.								•					
C. rurika									•				
C. cornuticaudata								•					
Nilotanypus sp.				•									
Labrundinia pilosella				•									
L. virescens			•										
Procladius denticulatus											•		
Psilotanypus bellus											•		
P. nietus											•		
Macropelopia sp.									•				
Orthocladiinae													
Thienemanniella sp.		•											
Corynoneura sp.			•										
Psectrocladius elatus				•									
P. nigrus			•										
P. simulans						•							
Cardiocladius sp.			•										
Trissocladius sp.		•											
Orthocladius sp.			•										
Eukiefferiella sp.			•										
Smittia sp.		•											
Cricotopus sp. 1						•							
C. sp. 2						•							
C. sp. 3						•							
C. sp. 4						•							
C. sp. 5						•							
C. c.f. *slossonae*							•						
C. c.f. *ceris*						•							
C. c.f. *exilis*							•						
Brillia par						•							
Diamesinae													
Diamesa sp.		•											
Chironominae-Chironomini													
Chironomus attenuatus gr.											•		
C. riparius gr.												•	
C. atritibia									•				
Cryptochironomus fulvus									•				
C. c.f. *argus*								•					
C. blarina									•				

Table II (continued)

TAXA	Trophic Condition Index / Empirical Biotic Index	CATEGORIES											
		N_0				N_1				N_2			
		0	1	2	3	4	5	6	7	8	9	10	11
Chironominae-Chironomini (cont.)													
Parachironomus pectinatellae							•						
P. abortivus gr.								•					
Harnischia curtilamellata						•							
Paracladopelma sp.					•								
Paratendipes sp.					•								
Microtendipes sp.					•								
Stenochironomus macateei				•									
S. taeniapenis				•									
Tribelos sp.							•						
Endochironomus nigricans				•									
Pseudochironomus sp. 1							•						
P. sp. 2							•						
Glyptotendipes amplus									•				
G. caulicola										•			
Polypedilum obtusum							•						
P. scalaenum									•				
P. pedatum							•						
P. griseopunctatum						•							
P. parvum							•						
P. convictum								•					
P. ontario							•						
P. halterale						•							
P. fallax									•				
P. simulans							•						
P. sp. 1 (*illinoense* gr.)							•						
Dicrotendipes nervosus							•						
D. neomodestus						•							
Chironominae-Tanytarsini													
Tanytarsini sp. 1						•							
Rheotanytarsus exiguus							•						
R. sp. 1						•							
Cladotanytarsus mancus gr.							•						
C. van der wulpi						•							
Calopsectra glabrescens				•									
C. c.f. *longiradius* (sp. 1 Rob.)					•								
C. c.f. *longiradius* (sp. 2 Rob.)				•									
C. neoflavella					•								
Calopsectra guerla					•								
Micropsectra sp.			•										
Paratanytarsus sp.				•									
Diptera-Other													
Ceratopogonidae							•						
Simuliidae								•					
Emplididae							•						
Chaoboridae							•						
Culicidae									•				
Psychodidae													
Psychoda sp.													•
Ephydridae													
Limnophora sp.												•	

Table II (continued)

TAXA	CATEGORIES											
Trophic Condition Index	N_0				N_1				N_2			
Empirical Biotic Index	0	1	2	3	4	5	6	7	8	9	10	11
Trichoptera												
Philopotamidae												
Chimarra obscura			•									
Hydropsychidae												
Hydropsyche bifida gr.				•								
H. simulans				•								
H. bettini					•							
Cheumatopsyche sp.						•						
Psychomyiidae												
Cyrnellus fraternus						•						
Neureclipsis crepuscularis				•								
Hydroptiliidae				•								
Ephemeroptera												
Heptageniidae												
Heptagenia sp.						•						
Stenonema pulchellum							•					
S. interpunctatum				•								
S. tripunctatum			•									
S. femoratum						•						
S. terminatum						•						
Ephemeridae												
Hexagenia limbata			•									•
H. atrocaudata			•									
Pentagenia sp.				•								
Baetidae												
Baetis sp.				•								
Isonychia sp.			•									
Caenidae												
Caenis sp.						•						
Tricorythodes sp.						•						
Leptophlebiiae												
Paraleptophlebia sp.			•									
Neuroptera												
Neohermes sp.				•								
Corydalus cornuta					•							
Climacia sp.			•									
Sialis sp.				•								
Plecoptera												
Perlidae												
Perlesta placida	•											
Acroneuria sp.				•								
Neumouridae												
Nemoura sp.				•								
Lepidoptera												
Paragyractis sp.				•								
Nymphulus sp.			•									
Paraponyx sp.				•								
Nepticula sp.				•								
Schendobius sp.				•								

Table II (continued)

TAXA	Trophic Condition Index / Empirical Biotic Index	CATEGORIES											
		N_0				N_1				N_2			
		0	1	2	3	4	5	6	7	8	9	10	11
Odonata-Zygoptera													
Agriidae													
Hetaerina americana						•							
Coenagriidae													
Argia tibialis							•						
A. moesta								•					
A. apicalis								•					
Enallagma atennatum								•					
E. exsulans								•					
Ischnura sp.									•				
Coeloptera													
Dytiscidae													
Deronectes sp.							•						
Elmidae													
Limnius sp.							•						
Stenelmis sexlineata								•					
Dubiraphia vittata							•						
Macronychus glabratus				•									
Microcylloepus pusillus				•									
Ancyronyx variegatus				•									
Dryopidae													
Helichus sp.							•						
Psephenidae													
Psephenus herricki						•							
Staphylinidae							•						
Curculionidae							•						
Haliplidae							•						
Ptiliidae							•						
Anthicidae							•						
Coccinellidae							•						
Gyrinidae													
Gyrinus sp.											•		
Heteroceridae										•			
Hemiptera													
Corixidae									•				
Gerridae													
Trepobates sp.								•					
Rheumatobates sp.								•					
Metrobates sp.								•					
Veliidae													
Rhagovelia sp.				•									
Mesoveliidae													
Mesovelia sp.								•					
Collembola							•						
Crustacea-Decapoda													
Orconectes rusticus								•					
Crustacea-Amphipoda													
Hyalella azteca							•						

Table II (continued)

TAXA	Trophic Condition Index / Empirical Biotic Index	CATEGORIES											
		N_0				N_1				N_2			
		0	1	2	3	4	5	6	7	8	9	10	11
Annelida-Oligochaeta													
Branchiobdellidae										•			
Branchuria sowerbii										•			
Tubificidae												•	
Naididae								•					
Enchytraeidae											•		
Annelida-Hirudinea													
Glossiphoniidae													
Placobdella rugosa										•			
Erpobdellidae													
Erpobdella sp.											•		
Dina sp.											•		
Mollusca-Gastropoda													
Physidae													
Physa sp.								•					
Pleuroceridae													
Goniobasis sp.						•							
Mollusca-Bivalvia													
Sphaeriidae													
Sphaerium sp.						•							
Pisidium sp.					•								
Unionidae													
Fusconia				•									
Coelenterata													
Hydridae				•									
Hydracarina						•							

(Figure 1) traversed by macroinvertebrate drift between Station 1 and 3 (about one mile = 1.5 km) and/or time of exposure to the STP effluent may have resulted in the very slight differences in taxonomic composition, whereas both Ekman grab and basket samples reflected an impact of the STP discharge on the total taxonomic composition collected.

Molluscs were present in grab samples at three of the four stations, in all basket collections, and at three of the five sampling locations in the drift net collections. The crayfish *Orconectes* was present in the basket collections at Station 1 in August, and all stations in the October collections, and was present in the drift net samples at Station 2W. Odonates, stoneflies, leeches, and other heavy-bodied invertebrates occurred sporadically in the samples. The importance of large organisms to biomass estimates was demonstrable and hampered data evaluation.

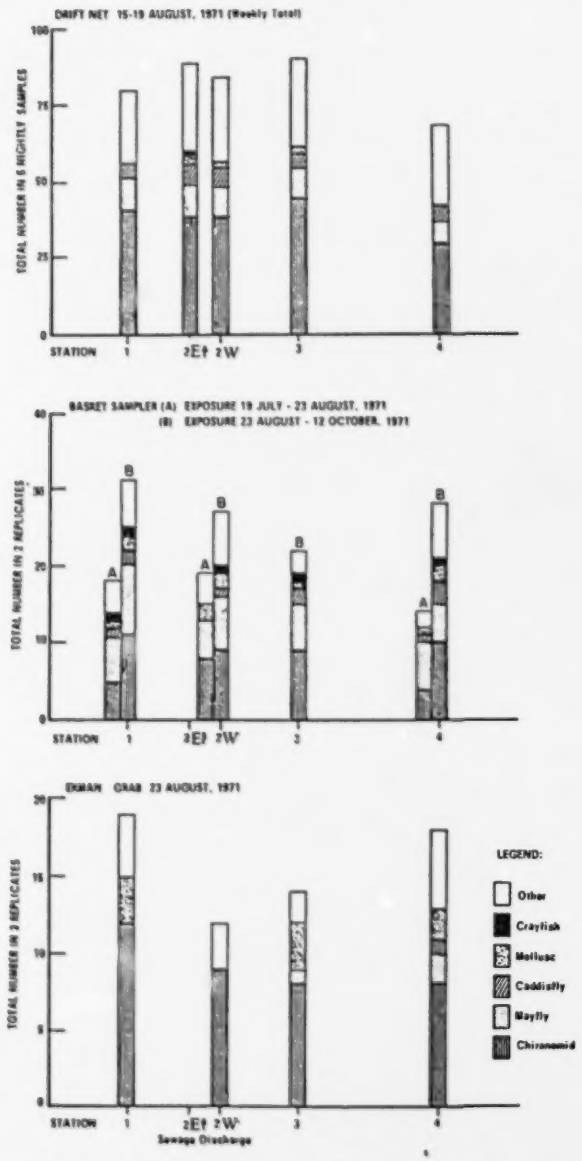
DRIFT NET 15-19 AUGUST, 1971 (Weekly Total)
TOTAL NUMBER IN 6 HIGHLY SAMPLES
STATION 1 2E† 2W 3 4
BASKET SAMPLER (A) EXPOSURE 19 JULY - 23 AUGUST, 1971
(B) EXPOSURE 23 AUGUST - 12 OCTOBER, 1971
TOTAL NUMBER IN 2 REPLICATES
STATION 1 2E† 2W 3 4
EKMAN GRAB 23 AUGUST, 1971
TOTAL NUMBER IN 3 REPLICATES
STATION 1 2E† 2W 3 4
Sewage Discharge
LEGEND:
Other
Crayfish
Mollusc
Caddisfly
Mayfly
Chironomid

Fig. 6. Composition of macroinvertebrate taxa (total) collected during 1971 in Ekman grab, drift net and basket sampler.

4.1. Counts of individual organisms

Ekman grab data for total individual counts (Figure 7, first column) assume a characteristic curve (Scott 1958) for benthic populations affected by mild organic discharge, i.e., at Station 1 (control station) moderate numbers of individual organisms existed ($1200\ m^{-2}$), and populations declined at Station 2 to $600\ m^{-2}$. The abundance of organisms increased (1500 and $3000\ m^{-2}$) at Station 3 and 4, respectively, due to the lessened impact of the STP discharge.

In grab samples at Station 3, the presence of heavy-bodied unionid mussels greatly exaggerates the wet and dry weight estimates (Figure 7, first column). Sphaeriids present at Station 1 represented a greater proportion of weight to the total weight of organisms than did *Goniobasis* snails at Station 4, resulting in dissimilar proportions of 'molluscs' to the other taxa represented.

Chironomidae were abundant at all stations, but the presence of heavy *Chironomus* larvae (14 mm length) at Station 4 resulted in dissimilar proportions of Chironomidae to the total weight of organisms compared with other stations. When molluscs and crayfish were not included in the graph of ash-free dry weight, it more closely resembled the one for individual counts.

Midges, mayflies, and snails, odonates, leeches and beetles contributed significantly to the individual counts of invertebrates inhabiting the August 23 basket samplers at Station 1 (Figure 7, column 2). The number of mayflies was greatly reduced at Station 2W, but formed a significant portion of the individuals at Station 4. A single crayfish was present in the basket at Station 1 and numerous *Goniobasis* snails were present at Station 4, which creates an illusion of comparatively similar proportions for the wet and dry weight curves in comparison to those for individual counts. Exclusion of these organisms from the weights presents a picture of subtle differences in the total biomass between stations. *Chironomus* larvae present at Station 2W were early instars and, unlike those in grab series, contributed little to total biomass. Odonates, leeches, and beetles, which may contribute significantly to the total biomass depending on life stage, comprised a larger percentage of organisms at Stations 1 and 2.

The counts of individual organisms for drift net data (Figure 7, third column) give the same picture as did the basket and grab data, i.e., a reduction of individuals at Station 2W and 3 and recovery at Station 4. The curves for wet and dry weights are greatly exaggerated if heavy-bodied crayfish and molluscs are included. Their exclusion yields a curve quite similar to the one for individual tallies. We found that insect biomass estimates from drift net collections offered uniformity not found in basket or grab collections as most specimens of each species are in the same stage of development and subsequently of uniform size and weight.

Note that the same data for Total Counts (Figure 7) are used to calculate indices for Figures 8–12 in the following discussion of biotic indices. It is evident from scanning Figures 7–11 for wet, dry and ash-free dry weights, all three expressions of biomass yield approximately the same interpretation for water quality status, and there is no clear advantage of one expression of biomass over another.

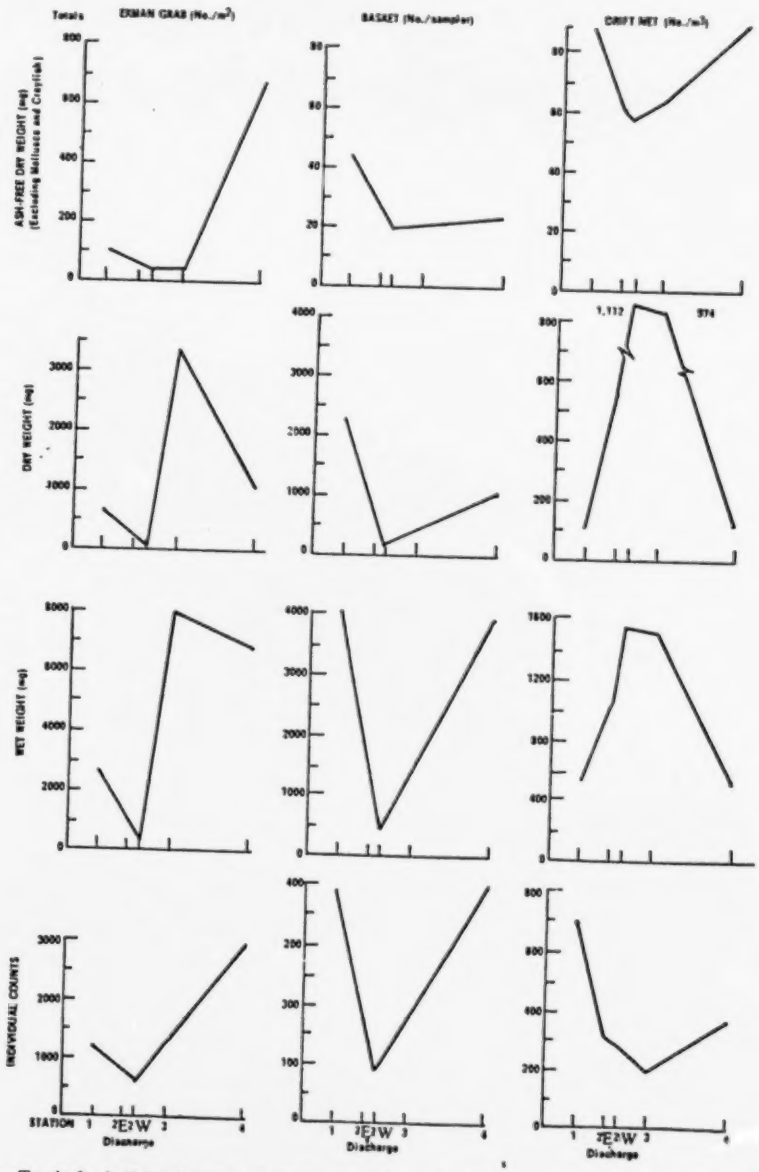

Fig. 7. Totals for individual counts (bottom row of figures), and biomass (wet weight, dry weight and ash-free dry weight) collected in Ekman Grab, Basket Sampler and drift net samples in the East Fork, Little Miami River, Ohio during 1971.

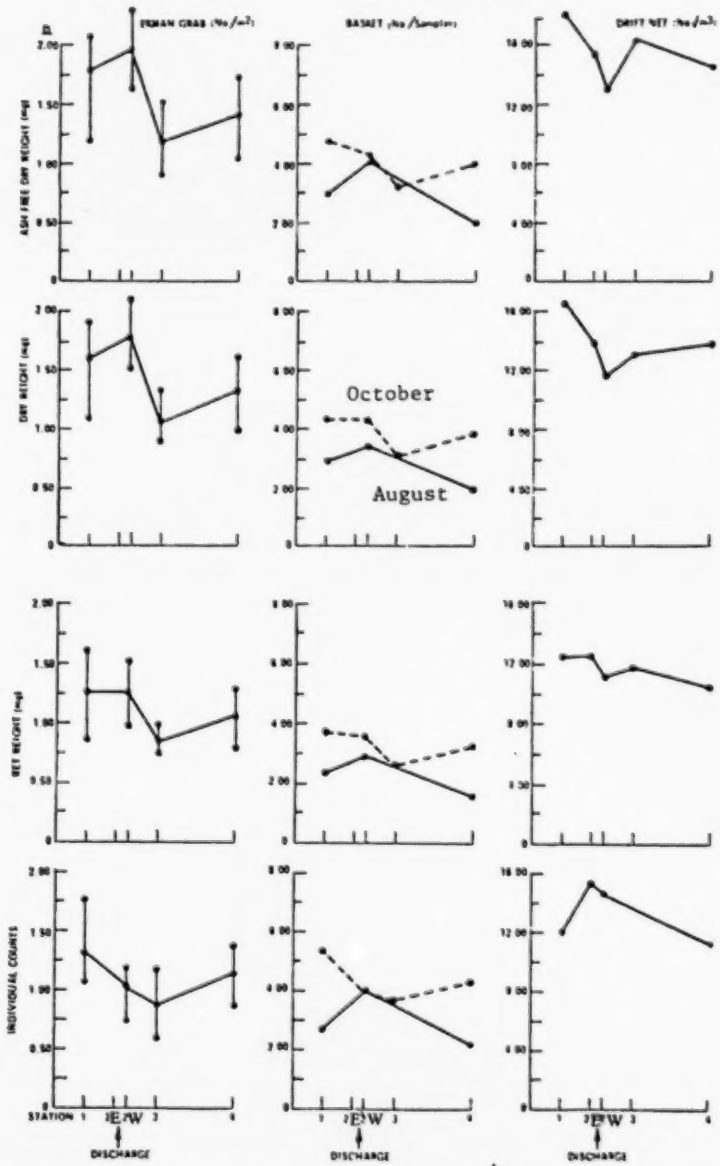

Fig. 8. Diversity Index (D) for data shown in Figure 7. For basket sampler collections, solid line for six week period ending in August and broken line for six week period ending in October.

4.2. Diversity index

Figure 8 represents a measure of species diversity (D) for individual counts and weights for all collections. Higher index values (greater species 'richness') are assumed to indicate less environmental stress, as greater diversity occurs among the total individuals collected. The index values for counts of individuals in Ekman grabs (Figure 8, first column) are lower for Stations 2W and 3 than for Stations 1 and 4. However, D's for dry and ash-free dry weight biomass estimates at Station 2W are higher, representing cleaner water. D's are high at Station 2W because, although the total number of taxa were only slightly lower at Station 2W (Figure 6), the biomass individual counts were composed of relatively diverse chironomid populations.

The counts of individual organisms in baskets yield highest D's at Station 2W. Biomass D's for the October basket (broken line) resemble the curve for individual counts because hellgrammites and crayfish in each sample weigh about the same. The biomass of crayfish in the drift net collections at Station 2W is sufficient to drive the curve downward – just the opposite of the individual count curve.

4.3. Community diversity index

Figure 9 shows individual count and biomass Community Diversity Index ($\bar{d}$). Unlike the graph (Figure 8) of D for the same grab data, $\bar{d}$'s for Station 2W are largest for both total counts and biomass estimates, approaching the 'clean water' category. The large number of molluscs collected at Station 3 causes the range of $\bar{d}$'s for biomass to incline toward the 'polluted water' category.

D-Bar for the August basket individual counts indicate that the community composition at Station 2W was representative of the cleanest water, and the composition at Stations 1 and 4, the worst. This apparent annomaly results from the occurrence of a disproportionate number and weight of *Stenonema interpunctatum* (75% of total 381 individuals) and 214 *Baetis* mayflies (54% of 396 individuals) in Station 1 and 4 basket samplers, respectively. The total 90 individuals in the Station 2 basket samplers was relatively evenly proportioned among the taxa, resulting in higher $\bar{d}$ as compared to the other stations. Thus, extreme caution is required when interpreting biotic 'indices', such as $\bar{d}$. Except for Station 2W, October basket collections (broken line) $\bar{d}$'s are representative of intermediate water quality. D-Bar for drift net total counts are all within the 'clean water' category when molluscs and crayfish are excluded. Biomass $\bar{d}$'s for drift net data at Stations 2W and 3 are within the intermediate water quality category if molluscs and crayfish are included (solid line). Exclusion of these weights (dotted line), however, presents a graph more closely resembling the one for counts of individuals.

Our experience in this study using $\bar{d}$ reveals that this index provides approximate indications of water quality regardless of using individuals counts or biomass values, and differences of 0.5 unit are not particularly significant to the water quality interpretation.

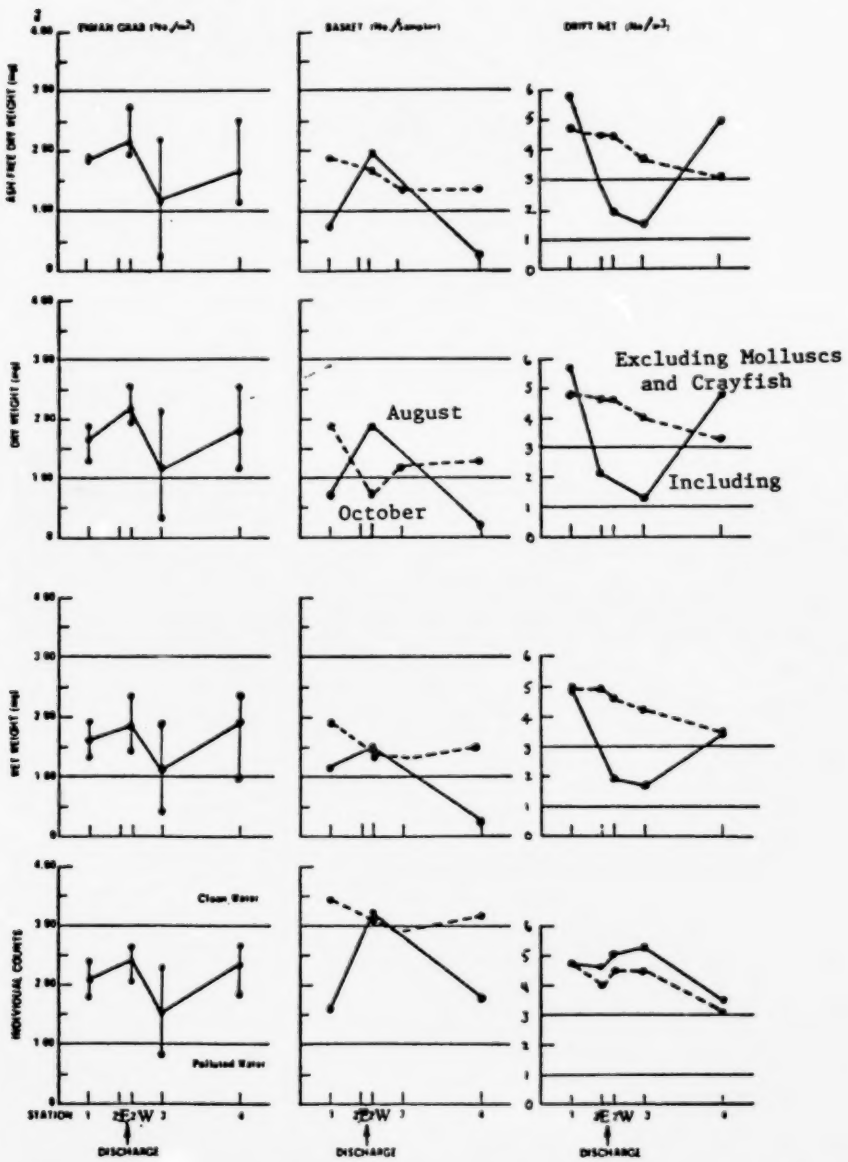

Fig. 9. Community Diversity Index ($\bar{d}$) for data shown in figure 7. For drift net samples, solid line includes molluscs and crayfish and dotted line excludes these heavy-bodied organisms.

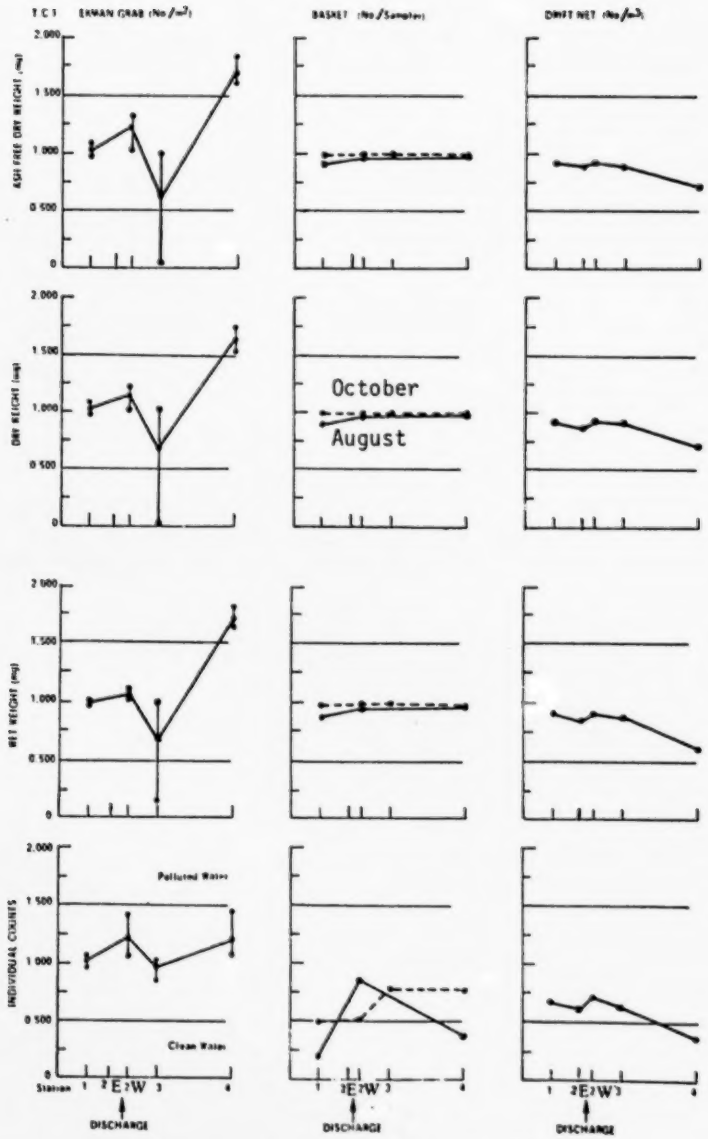

Fig. 10. Trophic Condition Index (TCI) for data shown in Figure 7.

4.4. TROPHIC CONDITION INDEX

The Trophic Condition Index (TCI) values for individual counts (Figure 10) in grabs are lower for Stations 1 and 3, indicating less eutrophic conditions as compared to Stations 2W and 4. However, the mean values for all stations lie within the mesotrophic water quality category. The range of TCI's for the biomass data fall within the oligotrophic category for Station 3 mostly due to presence of a single, large *Fusconia* mussel, assigned to the intolerant – 'N_0' Group in one sample (Table II).

For Ekman grab biomass, the TCI's for Station 4 are in the 'increasing eutrophy' category because 'pollution tolerant' leech, *Physa* snail, and large midges; *Chironomus*, *Glyptotendipes* and *Procladius*, were abundant. Note that according to D (Figure 7) and $\bar{d}$ (Figure 8) indices, the most degraded conditions existed at Station 3, whereas TCI shows the fauna at Station 3 was representative of the least degraded conditions.

TCI's for the August basket sampler individual counts (Figure 10, second column) indicate that the biological communities at Stations 1 and 4 are representative of increasing oligotrophy, and those at Station 2W represent increasing eutrophy, which is just the opposite information provided by D and $\bar{d}$ for the same data. The TCI index provides a mechanism for adjusting to disproportionate numbers (weights) of mayflies at Stations 1 and 4, i.e., use of mathematical weighting of taxa by pollutional category (Table II). TCI's for the biomass data reflect little perceptable difference between stations.

The curves for drift net individual counts and biomass are quite similar (molluscs and crayfish included). Based on known water quality characteristics (described under 'Study Area'), biomass TCI's accurately reflect the effects of pollution on the macroinvertebrate fauna, and do so without the exclusion of large, heavy-bodied organisms.

4.5. EMPIRICAL BIOTIC INDEX

Chutter's Emperical Biotic Index (EBI) for the individual counts in grab replicates (Figure 11) shows that the sample means for all stations lie within the 'enriched water' category, and the range of values for Station 2W lie in the 'polluted water' category. As was the case for TCI's, the biomass EBI's for Station 4 are in the polluted water category because 'pollution tolerant' organisms, which comprise a large percentage of the sample total weight, are assigned a quality value of '9' near the end of the quality value scale of '11' (Table II).

The individual count EBI's for the August baskets (solid line) yield curves that correspond to physical/chemical measurements at the stations, with Station 1 and 4 placed in the 'slightly enriched' category and Station 2W within the 'enriched water' category. The biomass EBI's show little difference between stations, and the October collections (dotted line) vary slightly in trophic status, regardless of station.

The EBI's for drift net total counts place Stations 1, 2E, 2W, and 3 within the 'enriched water' category, and Station 4 in the 'slightly enriched' water category. Drift net EBI's for biomass at the various stations all fall within the 'enriched water' category,

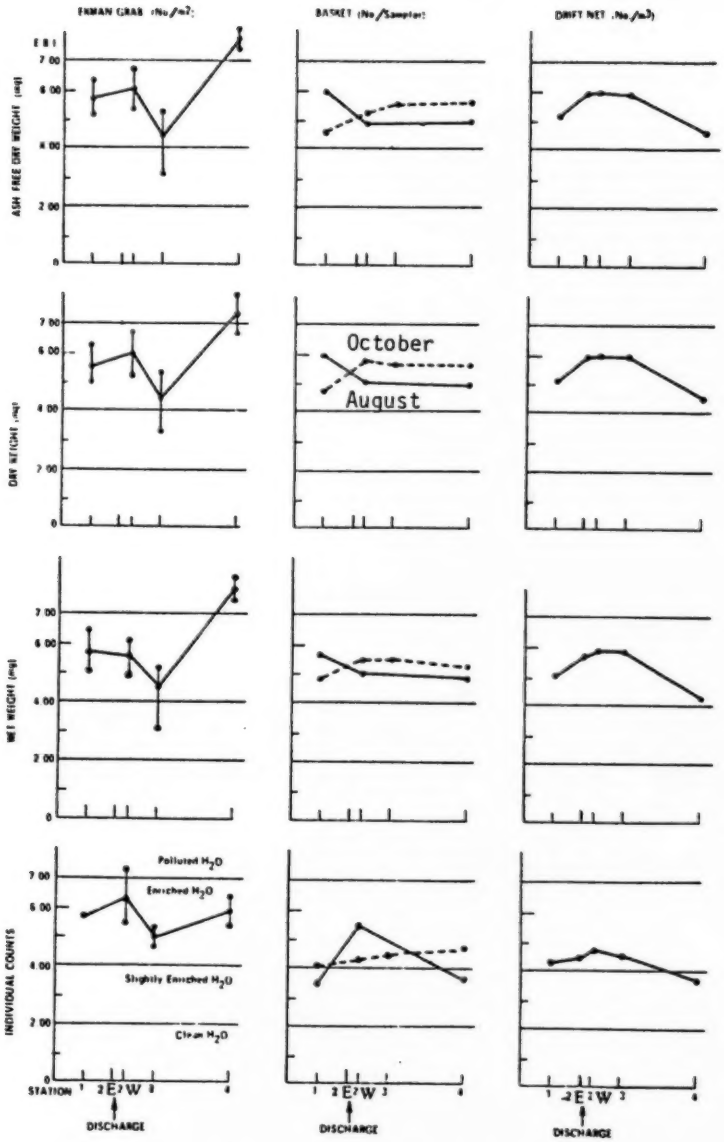

Fig. 11. Empirical Biotic Index (EBI) for data shown in Figure 7.

and the curve assumes a characteristic indication of biological recovery resulting from mild organic pollution.

Use of the EBI provides the most consistent and meaningful results of data interpretation as related to the benchmark water chemistry data collected during the sampling period. Also, use of either number of individuals per taxon or biomass per taxon yields the same interpretation of water quality status. Narf *et al.* (1984) reported similar successes for individual counts using a modified EBI type index.

4.6. Community composition by pollutional categories

The distribution of taxa (Table II, Figure 12) by pollution tolerance rank clearly shows that the preponderance (71%) of Total taxa (171) belong to the 'clean water' and 'facultative' indicator categories. The 'pollution tolerant' group contains just 10% of the total taxa, while 'clean water' taxa comprise 34% of the total taxa. Thus the relative distribution of taxa by pollution tolerance category informs us that the macroinvertebrate community in this stream segment is characteristic of a mildly eutrophic, well-buffered system. The assessment closely matches water chemistry and physics data for the stream segment.

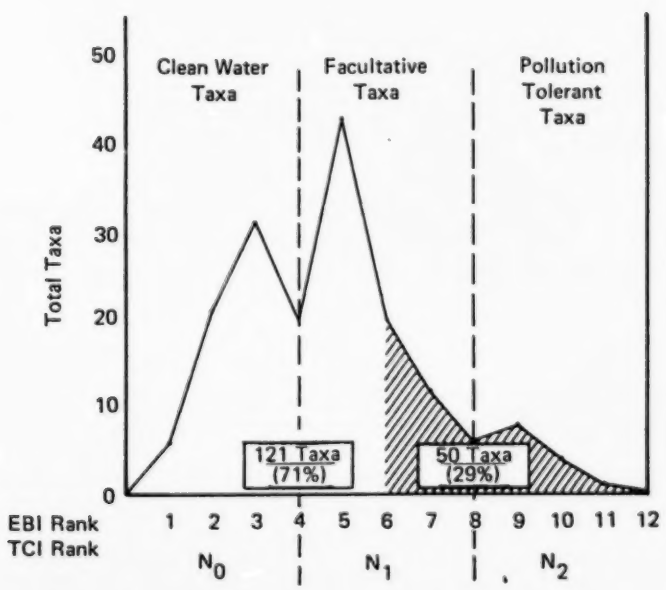

Fig. 12. Percent composition of 171 macroinvertebrate taxa (Table II) collected in the East Fork, Little Miami River, Ohio during 1971 by all sampling devices according to pollution tolerance rank using TCI and EBI.

5. Conclusions

(1) An evaluation of macroinvertebrate biomass estimates for the East Fork, Little Miami River, Ohio for data collected during the summer of 1971 shows that there are relatively minor differences in assessments of a sewage treatment plant (STP) discharge impacts using biomass as compared to individual counts of organisms (the traditional method) using a variety of commonly used biotic indices of water quality; Diversity Index (D), Community Diversity Index ($\bar{d}$), Trophic Condition Index (TCI) and Empirical Biotic Index (EBI).

(2) Of the biotic indices used for data evaluation, the TCI and EBI indices provide accurate and meaningful results for biotic status, whereas D and $\bar{d}$ results are less accurate and more variable regardless of value; wet, dry and ash-free dry weights or individual counts used to calculate the indices.

(3) The percent composition of macroinvertebrate taxa by pollutional category; 'clean water', 'facultative', and 'pollution tolerant', in a range 0–11 (higher number more pollution tolerant) collected in Ekman grab, rock-filled basket sampler and drift net provides clear evidence of the STP discharge on the macroinvertebrate communities, and matches benchmark physical and chemical data for the stream segment.

References

American Public Health Association *et al.*: 1981, 15th ed., *Standard Methods for the Examination of Water and Wastewater*, Washington, DC.

Bartsch, A. F. and Ingram, W. M.: 1959, 'Stream Life and the Pollution Environment', *Public Works* **90**, 104–110.

Brinkhurst, R. O., Hamilton, A. L., and Herrington, H. B.: 1968, 'Components of the Bottom Fauna of the St. Lawrence, Great Lakes', Great Lakes Institute, University of Toronto. Publ. No. 33. 49 pp.

Chutter, F. M.: 1972, 'An Empirical Biotic Index of the Quality of Water in South African Streams and Rivers', *Water Research* **6**, 19–30.

Kemp, P. H.: 1971, 'Chemistry of Natural Waters. Part VI. Classification of Waters', *Water Research* **5** 943–956.

Gaufin, A. R. and Tarzwell, C. M.: 1952, 'Aquatic Invertebrates as Indicators of Stream Pollution', *Public Health Repts* **67**(1), 57–64.

King, L. and Ball, R. C.: 1967, 'Comparative Energetics for a Polluted Stream', *Limnol. and Oceanog.* **12**(1), 27–33.

Lehmkuhl, D. M. and Anderson, N. H.: 1972, 'Microdistribution and Density as Factors Affecting the Downstream Drift of Mayflies', *Ecology* **53**(4), 651–666.

Mackay, R. J. and Kalff, J.: 1969, 'Seasonal Variation in Standing Crop and Species Diversity of Insect Communities in a small Quebec Stream', *Ecology* **50**(1), 101–109.

Mason, W. T., Jr. and Anderson, J. B., Kreis, R. D., and Johnson, W. C.: 1970, 'Artifical Substrate Sampling; Macroinvertebrates in a Polluted Reach of the Klamath River, Oregon', *J. Water Pollut. Contr. Fed.* **42**(2), 315–328.

Mason, W. T., Weber, C. I., Lewis, P. A., and Julian, E. C.: 1973. 'Factors Affecting the Performance of Basket and Multiplate Macroinvertebrate Samples'. *Freshwater Biology* **3**, 409–436.

Mason, W. T., Lewis, P. A., and Weber, C. I.: 1983, 'An evaluation of Macroinvertebrate Biomass Methodology', *Environmental Monitoring and Assessment.* **3**, 29–44.

Narf, R. P., Lange, E. L., and Wildman, R. C.: 1984, 'Statistical procedures for Applying Hilsenhoff's Biotic Index', *J. Freshwater Ecology.* **2**(5), 441–448.

Scott, D. C.: 1958, 'Biological Balance in Streams', *Sewage and Industrial Wastes* **30**(9), 1169–1173.

Wilhm, J. L.: 1970, 'Range of Diversity Index in Benthic Macroinvertebrate Populations', *J. Water Pollut. Contr. Fed.* **42**(5), R 221–224.

Waters, T. F.: 1966, 'Production Rate, Population Density, and Drift of a Stream Invertebrate', *Ecology* **47**(4), 595–604.